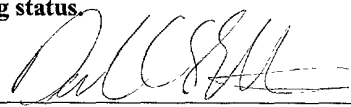


FORM PTO-1390 (REV 10-2000)		U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE		ATTORNEY'S DOCKET NUMBER 87805-9016	
<b>TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371</b>				U.S. APPLICATION NO. (If known, see 37 CFR 1.5) <div style="font-size: 24pt; font-weight: bold;">09/700321</div>	
INTERNATIONAL APPLICATION NO. PCT/GB99/01574		INTERNATIONAL FILING DATE 17 May 1999 (17.05.99)		PRIORITY DATE CLAIMED 15 May 1998 (15.05.98)	
TITLE OF INVENTION      VIDEO SIGNAL PROCESSING					
APPLICANT(S) FOR DO/EO/US      Martin Weston and William Beninfield Collis					
<p>Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:</p> <ol style="list-style-type: none"> <li>1. <input checked="" type="checkbox"/> This is a <b>FIRST</b> submission of items concerning a filing under 35 U.S.C. 371.</li> <li>2. <input type="checkbox"/> This is a <b>SECOND</b> or <b>SUBSEQUENT</b> submission of items concerning a filing under 35 U.S.C. 371.</li> <li>3. <input type="checkbox"/> This is an express request to promptly begin national examination procedures (35 U.S.C. 371(f)).</li> <li>4. <input type="checkbox"/> The US has been elected by the expiration of 19 months from the priority date (PCT Article 31).</li> <li>5. <input checked="" type="checkbox"/> A copy of the International Application as filed (35 U.S.C. 371(c)(2))               <ol style="list-style-type: none"> <li>a. <input type="checkbox"/> is attached hereto (required only if not communicated by the International Bureau).</li> <li>b. <input checked="" type="checkbox"/> has been communicated by the International Bureau.</li> <li>c. <input type="checkbox"/> is not required, as the application was filed in the United States Receiving Office (RO/US).</li> </ol> </li> <li>6. <input type="checkbox"/> An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).</li> <li>7. <input checked="" type="checkbox"/> Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))               <ol style="list-style-type: none"> <li>a. <input type="checkbox"/> are attached hereto (required only if not communicated by the International Bureau).</li> <li>b. <input type="checkbox"/> have been communicated by the International Bureau.</li> <li>c. <input type="checkbox"/> have not been made; however, the time limit for making such amendments has NOT expired.</li> <li>d. <input checked="" type="checkbox"/> have not been made and will not be made.</li> </ol> </li> <li>8. <input type="checkbox"/> An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).</li> <li>9. <input type="checkbox"/> An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).</li> <li>10. <input type="checkbox"/> An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).</li> </ol> <p><b>Items 11 to 16 below concern document(s) or information included:</b></p> <ol style="list-style-type: none"> <li>11. <input type="checkbox"/> An Information Disclosure Statement under 37 CFR 1.97 and 1.98.</li> <li>12. <input type="checkbox"/> An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.</li> <li>13. <input checked="" type="checkbox"/> A <b>FIRST</b> preliminary amendment.  <input type="checkbox"/> A <b>SECOND</b> or <b>SUBSEQUENT</b> preliminary amendment.</li> <li>14. <input type="checkbox"/> A substitute specification.</li> <li>15. <input type="checkbox"/> A change of power of attorney and/or address letter.</li> <li>16. <input checked="" type="checkbox"/> Other items or information:            Courtesy copy of Replacement Pages 2 and 4            and Drawing Sheet 1/1         </li> </ol>					

"Express Mail" mailing label number EL716053422 US

I hereby certify that this paper or fee is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 CFR 1.10 on the date of my signature and is addressed to Box PCT, Assistant Commissioner for Patents, Washington, D.C. 20231.

Nancy Dragolovich  
 (Typed or printed name of person mailing paper or fee)  
  
 (Signature of person mailing paper or fee)  
 Date of Deposit 14 November 2000

U.S. APPLICATION NO. (if known) <b>09/700321</b>		INTERNATIONAL APPLICATION NO. <b>PCT/GB99/01574</b>		ATTORNEY'S DOCKET NUMBER <b>87805-9016</b>	
17. <input checked="" type="checkbox"/> The following fees are submitted: <b>BASIC NATIONAL FEE (37 CFR 1.492(a)(1)-(5)):</b> Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO ..... <b>\$1000.00</b> International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO ..... <b>\$860.00</b> International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO ..... <b>\$710.00</b> International preliminary examination fee paid to USPTO (37 CFR 1.482) but all claims did not satisfy provisions of PCT Article 33(1)-(4) ..... <b>\$690.00</b> International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(1)-(4) ..... <b>\$100.00</b> <div style="text-align: right;"><b>ENTER APPROPRIATE BASIC FEE AMOUNT =</b></div>				<b>CALCULATIONS</b> PTO USE ONLY	
Surcharge of <b>\$130.00</b> for furnishing the oath or declaration later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(e)).				\$	
CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	15 - 20 =	0	X \$18.00	\$ 0	
Independent claims	2 - 3 =	0	X \$80.00	\$ 0	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+ \$270.00	\$	
<b>TOTAL OF ABOVE CALCULATIONS =</b>				\$ 860.00	
<input type="checkbox"/> Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by 1/2.				\$	
<b>SUBTOTAL =</b>				\$ 860.00	
Processing fee of <b>\$130.00</b> for furnishing the English translation later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(f)).				\$	
<b>TOTAL NATIONAL FEE =</b>				\$ 860.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). <b>\$40.00</b> per property				\$	
<b>TOTAL FEES ENCLOSED =</b>				\$ 860.00	
				Amount to be refunded:	\$
				charged:	\$
a. <input checked="" type="checkbox"/> A check in the amount of \$ <u>860.00</u> to cover the above fees is enclosed.					
b. <input type="checkbox"/> Please charge my Deposit Account No. _____ in the amount of \$ _____ to cover the above fees. A duplicate copy of this sheet is enclosed.					
c. <input checked="" type="checkbox"/> The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. <u>13-3080</u> . A duplicate copy of this sheet is enclosed.					
<b>NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.</b>					
SEND ALL CORRESPONDENCE TO:  Derek C. Stettner Michael Best & Friedrich LLP 100 East Wisconsin Avenue Milwaukee, WI 53202					
				 SIGNATURE:	
				Derek C. Stettner	
				NAME	
				37,945	
				REGISTRATION NUMBER	

09/700321

529 Rec'd PCT/PTC 14 NOV 2000

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re

International Application of

Weston, et al.

International Application No.  
PCT/GB99/01574

International Filing Date:  
17 May 1999

VIDEO SIGNAL PROCESSING

PRELIMINARY AMENDMENT

BOX PCT  
Assistant Commissioner for Patents  
Washington, DC 20231

Sir:

Please amend the application as follows prior to calculation of the filing fees.

IN THE CLAIMS

In Claim 5, line 1, delete "any one of the preceding claims" and insert --Claim 1--.

In Claim 6, line 1, delete "any one of Claims 1 to 4" and insert --Claim 1--.

In Claim 7, line 1, delete "any one of the preceding claims" and insert --Claim 1--.

In Claim 12, line 1, delete "any one of Claims 8 to 11" and insert --Claim 8--.

In Claim 13, line 1, delete "any one of Claims 8 to 11" and insert --Claim 8--.

In Claim 14, line 1, delete "any one of Claims 8 to 13" and insert --Claim 8--.

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## REMARKS

The claims have been amended to remove multiple dependent claims and to conform to U.S. Patent Office practice. Please enter this amendment before calculating the filing fees.

Respectfully submitted,

2008

Derek C. Stettner  
Reg. No. 37,945

File No. 87805-9016

Michael Best & Friedrich LLP  
100 East Wisconsin Avenue  
Milwaukee, WI 53202-4108  
(414) 271-6560

09/700321

VIDEO SIGNAL PROCESSING

This invention relates to video signal processing and is particularly concerned with non-linear filtering.

5 It has been found that in a wide variety of video signal processes - including de-interlacing, decoding, enhancement, noise reduction, and standards conversion - considerable advantage can be secured by the use of complex non-linear filters. It has been found in particular that polynomial filters can be very useful. In many applications, quadratic behaviour in the  
10 filter is not sufficient and third or higher orders are typically necessary. Where real time operation is required, hardware implementations are usually essential and the hardware costs of such high order polynomial filters are substantial.

It is an object of the present invention to provide improved methods  
15 and apparatus in video signal processing which offer third or higher order behaviour in a relatively simple filter architecture.

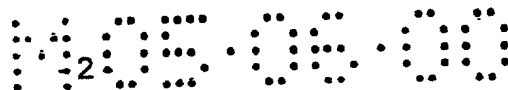
Accordingly, the present invention consists, in one aspect, in a method of video signal processing, comprising the steps of conducting three linear filtering operations on an input video signal to produce three filtered signals,  
20 each linear filtering operation comprising the taking of a weighted sum of pixels; and multiplying together said three filtered signals to produce an output video signal.

Suitably, the weighted sum is taken over pixels of the input video signal defined by a filter aperture and, preferably, all three linear filtering operations  
25 have the same filter aperture.

In one embodiment, for at least one linear filtering operation, the taking of a weighted sum of pixels includes the output pixel of the respective linear filtering operation.

In another aspect, the present invention consists in apparatus for video  
30 signal processing comprising an input terminal for receiving an input video signal; first, second and third linear filters each connected with the input terminal and arranged to provide an output through taking a weighted sum of pixels; a first multiplier for multiplying together the respective outputs of the

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first and second filters; and a second multiplier for multiplying together the respective outputs of the first multiplier and the third filter to produce an output video signal.

Advantageously, a filter is interposed between the output of the first multiplier and the second multiplier.

Preferably, the apparatus further comprises a linear filter path connected with the input terminal, and a combiner for combining the outputs of the linear filter path with the output of said second multiplier.

Suitably, a filter is interposed between the output of the second multiplier and said combiner.

The invention will now be described by way of example with reference to the accompanying drawings in which:

Figure 1 is a block diagram of video signal processing apparatus according to the invention, in the form of a vertical de-interlacing filter; and

Figure 2 is a diagram similar to Figure 1, illustrating a modification.

The example will be taken of a de-interlacer and, for reasons of clarity, a de-interlacer will be described that utilises only vertical information. It will be understood that horizontal and temporal information could be included in ways which will be immediately evident to the skilled reader.

In Figure 1, the new architecture can be seen to consist of two signal paths. A linear signal path 10 contains a traditional, vertical, six tap, linear filter ( $h_{lin}$ ) which has a typical  $\sin(x)/x$  structure. If this were to be used without the non-linear signal path it would produce reasonable pictures, but they would contain some artefacts due to the interpolation process, notably jaggling on diagonal and curved edges.

In the non-linear signal path 20, the output of two four point linear filters ( $h_1$  and  $h_2$ ) are multiplied together and passed through a two point linear filter ( $h_4$ ). The output of this is then multiplied with the output of a five point linear filter ( $h_3$ ). The resulting signal is filtered through another two point linear filter ( $h_5$ ) before being added on to the linear path. Although in this case the

filter lengths are 4, 5 and 2, larger filters with more taps can be used to give better results. The lengths (or more generally, the sizes) of the filters need not be related and can be made larger or smaller to provide different trade-offs between quality and cost.

5 It will be recognised that the arrangement of Figure 1 serves to generate the "missing" lines in a de-interlacing operation. These new lines will be combined in a multiplexer with the (suitably delayed) "original" lines.

The filter coefficients can be selected by 'training' the filter on real pictures. In this example of de-interlacing, a still frame is taken and split into  
10 fields. A set of coefficients is used to estimate Field 2 from Field 1 and the mean squared error between the estimate of Field 2 and the original Field 2 is measured. A genetic algorithm can then be used to search the multi-dimensional filter space for the set of filter coefficients that gives the lowest mean squared error.

15 If the described non-linear de-interlacer is tested on the EBU/SMPTE test picture "Girl with Toys", the non-linear path is found to reduce the average mean squared error by approximately 15% with respect to the linear filter. There is also a noticeable reduction in jaggling.

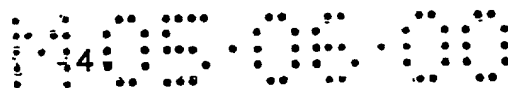
A polynomial filter with the same number of input pixel taps produces  
20 an almost equivalent reduction in error. However, a major advantage of this new architecture over the polynomial filter can be seen by considering the number of multiplications of pixels; multiplications of pixels by a constant; and additions, that each filter requires. These are shown in Table 1.

	Polynomial Filter	New Architecture
Multiplication	50	2
Multiplication by a constant	34	23
Additions	34	24

Table 1 : Comparison of complexity of filters

25

It can be seen that the largest reduction is in the multiplication of pixels. This is particularly significant as these are the most expensive to implement.



In summary, the new architecture is able to reduce many of the artefacts associated with traditional linear interpolation whilst being relatively simple to implement.

Figure 2 illustrates a modification in which the architecture is simplified through omission of the filters  $h_4$  and  $h_5$ . In other words, the direct product is formed of the outputs of filters  $h_1$ ,  $h_2$  and  $h_3$  without intervening filtering of the product of the outputs of filters  $h_1$  and  $h_2$ . This may under some circumstances produce less ideal filter behaviour, but the reduction in hardware complexity will often more than compensate. A particular advantage is that the three remaining filters can all make use of the same memory architecture.

It should be understood that this invention has been described by way of example only and that a wide variety of modifications are possible without departing from the scope of the invention. Thus, whilst the separation into linear and non-linear paths offers important advantages, such as the option to preserve higher bit accuracy in the linear path, it will not always be appropriate. Similarly, the described use of vertical filters is - as has been explained - merely an example. Horizontal, vertical and temporal filters can be employed and filters can have one, two or three of these dimensions. Whilst Finite Impulse Response (FIR) filters will be important, the invention also encompasses other forms of linear filter such as recursive filters which include the output pixel in the weighted sum. The filters which are to be multiplied together need not be of the same category. However, providing three FIR or transversal filters with the same filter aperture ensures that in the multiplication of the three filtered signals, all possible cross products of input pixels are made available.

It will be recognised that although de-interlacing has been chosen as an example, filters according to the present invention can be applied to other problems in video processing, including composite to component decoding, enhancement, noise reduction, up and down conversion and standards conversion -.

**CLAIMS**

1. A method of video signal processing, comprising the steps of conducting three linear filtering operations on an input video signal to produce three filtered signals, each linear filtering operation comprising the taking of a weighted sum of pixels; and multiplying together said three filtered signals to produce an output video signal.
2. A method according to Claim 1, wherein said weighted sum is taken over pixels of the input video signal defined by a filter aperture.
3. A method according to Claim 2, wherein all three linear filtering operations have the same filter aperture.
4. A method according to Claim 1, wherein, for at least one linear filtering operation, the taking of a weighted sum of pixels includes the output pixel of the respective linear filtering operation.
5. A method according to any one of the preceding claims, wherein the product of two of said filtered signals is formed and a linear filtering operation conducted on that product, prior to multiplication of said product by the third filtered signal.
6. A method according to any one of Claims 1 to 4, wherein said three filtered signals are multiplied together without intervening filtering of the three filtered signals.
7. A method according to any one of the preceding claims, wherein a further linear filtering operation is conducted in parallel on the input video signal, with the result of said further linear filtering operation being combined with the multiplication product of said three filtered signals to produce an output video signal.

8. Apparatus for video signal processing comprising an input terminal for receiving an input video signal; first, second and third linear filters each connected with the input terminal and arranged to provide an output through taking a weighted sum of pixels; a first multiplier for multiplying together the respective outputs of the first and second filters; and a second multiplier for multiplying together the respective outputs of the first multiplier and the third filter to produce an output video signal.
9. Apparatus according to Claim 8, wherein said weighted sum is taken over pixels of the input video signal defined by a filter aperture.
10. Apparatus according to Claim 9, wherein said three linear filters have the same filter aperture.
11. Apparatus according to Claim 8, wherein at least one linear filter is arranged to take a weighted sum of pixels which includes the output pixel of the respective linear filter.
12. Apparatus according to any one of Claims 8 to 11, wherein there is further provided a linear filter connected between the output of said first multiplier and the input to said second multiplier.
13. Apparatus according to any one of Claims 8 to 11, wherein there is a direct connection between the output of said first multiplier and the input to said second multiplier.
14. Apparatus according to any one of Claims 8 to 13, wherein the apparatus further comprises a linear filter path connected with the input terminal, and a combiner for combining the outputs of the linear filter path with the output of said second multiplier.
15. Apparatus according to Claim 6, wherein a filter is interposed between the output of the second multiplier and said combiner.

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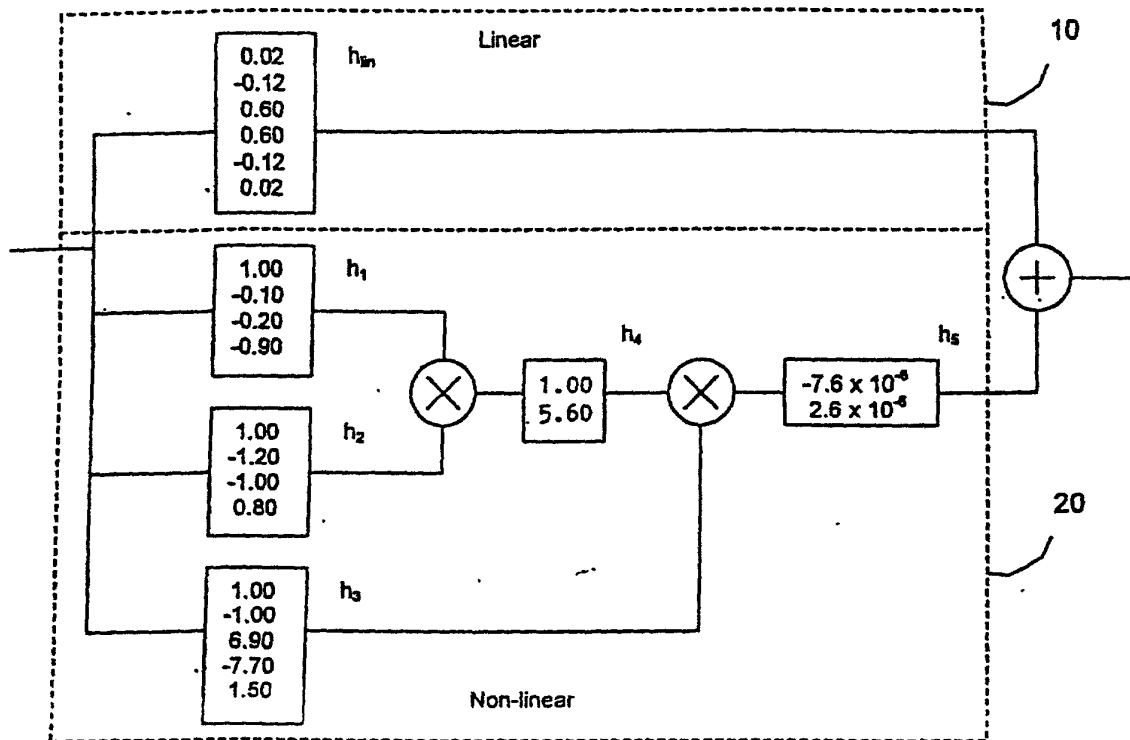


Figure 1

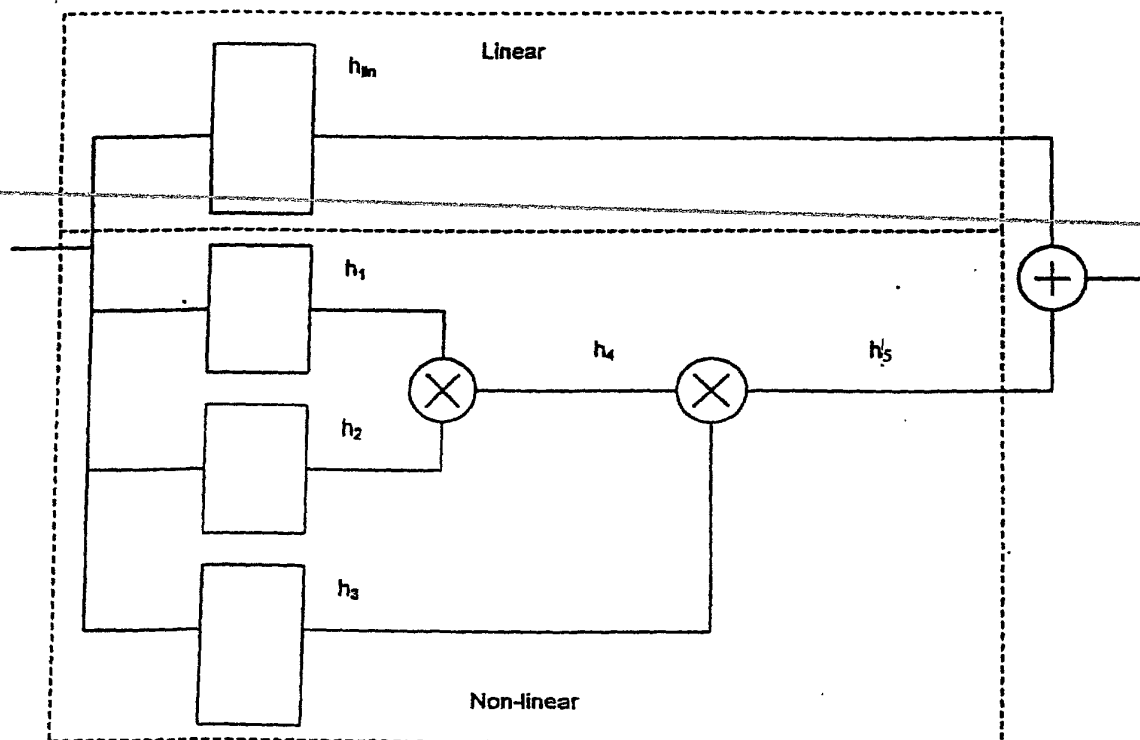


Figure 2

**Declaration and Power of Attorney For Patent Application**

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am an original, first and joint inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled VIDEO SIGNAL PROCESSING (Attorney Docket No. 87805-9016), the specification of which was filed with my authority, on November 14, 2000 as Application Serial No. 09/700,321.

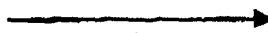
I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims referred to above.

I acknowledge the duty to disclose to the Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, §1.56.

As a named inventor, I hereby appoint the following registered practitioners to prosecute this application and transact all business in the Patent and Trademark Office connected therewith:

Customer Number

23409



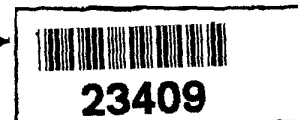
23409

PATENT TRADEMARK OFFICE

DIRECT ALL COMMUNICATIONS IN OR PERTAINING TO THIS APPLICATION TO:

Customer Number

23409



23409

PATENT TRADEMARK OFFICE

09700321-11400

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of the foreign application for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application

(Number)	(Country)	(Day/Month/Year Filed)
PCT/GB99/01574	PCT	17 May 1999
9810555.4	United Kingdom	15 May 1998

The undersigned to this Declaration and Power of Attorney hereby authorize the U.S. attorneys named herein to accept and follow instructions from Mathys & Squire, 100 Gray's Inn Road, London WC1X 8AL, England as to any actions to be taken in the U.S. Patent and Trademark Office regarding this application without direct communication between the U.S. attorneys and the undersigned. In the event of a change in the person(s) from whom instructions may be taken, the undersigned will so notify the U.S. attorneys.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

1-00 Full name of first joint inventor: Martin Weston

Inventor's signature M Weston  
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Residence: Hampshire England ENG  
Citizenship: Great Britain  
Post Office Address: 7B Weston Road  
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Full name of second joint inventor: William Beninfield Collis

Inventor's signature \_\_\_\_\_  
Date: \_\_\_\_\_  
Residence: Southampton, Hampshire England ENG  
Citizenship: Great Britain  
Post Office Address: Lee's Cottage, 19 Jones Lane  
Hyvhe, Southampton, Hampshire SO45 6AW England

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of the foreign application for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application

(Number)	(Country)	(Day/Month/Year Filed)
PCT/GB99/01574	PCT	17 May 1999
9810555.4	United Kingdom	15 May 1998

The undersigned to this Declaration and Power of Attorney hereby authorize the U.S. attorneys named herein to accept and follow instructions from Mathys & Squire, 100 Gray's Inn Road, London WC1X 8AL, England as to any actions to be taken in the U.S. Patent and Trademark Office regarding this application without direct communication between the U.S. attorneys and the undersigned. In the event of a change in the person(s) from whom instructions may be taken, the undersigned will so notify the U.S. attorneys.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Full name of first joint inventor: Martin Weston

Inventor's signature \_\_\_\_\_

Date: \_\_\_\_\_

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Full name of second joint inventor: William Beningfield Collis

Inventor's signature \_\_\_\_\_

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